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ELECTROPLATING

James G. Farrell

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Electrometallurgical industries comprise an important segment of the world's manufacture of metal products. These industries involve three major categories: electrowinning, electrorefining and electroplating. Electrowinning consists of purifying raw ore to a relatively pure metal by electrolysis. Extraction of aluminum from bauxite is an example. Electrorefining involves electrolysis of metallic solutions to recover or produce extremely pure metal. Recovery of precious metals is often done by electrorefining. Electroplating involves the coating of one metal or object with another metal for various reasons. The chief reasons are the protection of a part from corrosion or its beautification. Another type of electroplating is done to repair or replace worn surfaces and in some cases to form an entirely new metal surface for some nonmetallic object. This last type of electroplating is generally called electroforming.¹ This article will be concerned with electroplating.

BASIC PRINCIPLES

The essential parts of a typical electroplating system are: (1) the plating bath, which contains a compound of the metal to be deposited; (2) a source of direct current (DC) electricity; (3) the object to be coated (the basis metal); and (4) a sheet or bar of the plating metal. The negative terminal of the DC source is connected to the object (the cathode), while the positive terminal is connected to the

bar of plating metal (the anode). When both the electrodes are immersed in the bath and current applied ionic action results.

The metal ions are freed from the bath and migrate to the surface of the cathode where they are transformed to the metallic state and attach to the suspended cathode. Anode metal dissolves in the bath replacing the ions lost by the bath to the surface of the cathode. These two electrode processes result in the transfer of the plating metal from the bulk bar to form a coating on the basis metal.

In principle, the thickness of a plated coating is determined by the amperage and the time the current is applied. Losses, however, do occur to render electroplating less than one hundred percent efficient. Efficiency is generally defined by the ratio of metal actually deposited to that called for by Faraday's laws. More simply stated, plating efficiency is a ratio of actual deposit to theoretical deposit. Actual deposits can be affected by mechanical losses, oxidation-reduction reactions of ions in the bath, electrical conduction losses and gas deposits on the cathode.²

BATHS

Baths consist of water containing either a simple salt or complex ions to which other chemicals are added. Simple salts might consist of copper sulfate, nickel sulfate or tin sulfate, for example. More complex ions in aqueous solution

in rectifiers avoids the problems of disc rectifiers. Large plating shops usually use motor-generators.⁵

BASIS METALS and BARS

The prevention of corrosion by plating requires the exclusion of electrolytes from the basis metal. Galvanic action can be precluded by the proper selection of the plating metal. The hydrogen scale of galvanic potentials determines which of two metals will replace each other or "corrode" preferentially when placed in contact with each other. Metals above hydrogen are generally considered electrochemically active while those below hydrogen are generally inert. A protective coating of one metal over another may protect the base metal or may accelerate its corrosion, depending on whether the coating is more or less "noble" than the base and whether the base is entirely covered. If pinholes exist in the plating local galvanic cells are set up. Corrosion will follow the incomplete covering.⁶

The most commonly ^{used} plating metals are: copper, nickel, chromium, tin, cadmium, zinc, silver and gold. Other metals which have more limited use in electroplating are: iron, lead, rhodium, indium, platinum and cobalt. While several alloys can be electroplated, only brass and nickel-tin have extensive use. The particular aqueous solution used to plate with these metals successfully requires a specific solution of cyanides sulfates or acids of these metals. Optimum ion exchange

occurs at a certain temperature and a certain current density for each metal. Literature of the industry should be consulted before actual plating is attempted.

The coating of plastics and other non-conducting materials was an early development in the history of electroplating. The process required making the surface both hydrophilic and conducting. First the article was abraded mechanically or etched chemically. Then a thin film of graphite was applied from a colloidal suspension or a thin film of silver from chemical reduction was formed. Electrodeposition of a much thicker coating, almost always copper, then took place. Other metals were then plated over the copper. Today ABS plastic articles are specially etched and can receive thin electroplated coatings.⁷

PRETREATMENT

The final appearance of plated articles depends markedly on pretreatment. Degreasing, cleaning, pickling and bright dipping have great influence on the quality and performance of the plated part. Petroleum based solvents are often used to remove grease by soaking, dipping or spraying the part. Chlorinated solvents may be used at elevated temperatures as vapors to remove grease. Chemical cleaning may be done with highly alkaline cleaners containing wetting agents. Emulsifiable solvent cleaners combine the properties of solvent and alkaline cleaners. Several proprietary cleaners are available. Many

cleaners may be used with ultrasonic agitation baths which are particularly successful in removing soil from inaccessible areas such as pores, cracks and crevices.⁸

Acid dipping removes the alkaline film carried from the cleaner and the oxide on the metal. Pickling consumes some of the metal (and acid) and does a more thorough job of cleaning badly smutted parts.⁹ These procedures prevent contamination of bath solutions and the generation of unwanted gas during the plating process. This gas may cause embrittlement of the plate which is the deposition of hydrogen ions on the cathode. The hydrogen ions are reduced to hydrogen atoms within atomic voids in the cathode causing increased pressure and microstresses.¹⁰ Pickling baths must be carefully selected for their chemical properties, strengths and times of application.

SAFETY

Acid dipping, plating and pickling operations generate hydrogen gas which might unite with oxygen generated at an anode forming an explosive mixture. Hydrogen, therefore, must be carefully vented to prevent an explosion. Other strong reducing agents must also be carefully handled and stored to prevent initiation of combustion with oxygen. Distinct separation of storerooms should be provided for strong oxidizing agents such as perchlorates, chlorates, peroxides, etc. Some compounds such as ammonium nitrate and ammonium dichromate contain both reducing and oxidizing groups in their structure and may explode

if heated sufficiently. All containers should be properly labelled as to contents and storage requirements.¹¹

Cyanides coming into contact with acids liberate hydrocyanic acid which is very toxic. Every precaution should be taken to prevent acid-cyanide contact in storage, the shop or shop drains. Acids and alkalis cause skin burns by severe dehydration of tissue until they are neutralized. Soda ash should be available in several key locations in the shop for neutralization of acid spills. Gloves should be worn when handling corrosive chemicals.

Organic solvents may cause dermatitis, attack on the nervous system and poisonous reactions. Volatile degreasers, notably the chlorinated type, may be inhaled and enter the blood and attack the brain and other organs. Ventillation is necessary throughout a plating shop. It must be designed to remove fumes from all shop operations.¹²

can be provided by such compounds as sodium stannate, sodium argento-cyanide or chromic acid. Usually organic compounds, in colloidal suspension, are added to the bath solution even though their contribution to the actual electroplating process is not fully understood. Perhaps the most accepted theory is that the addition agent (especially if colloidal) codeposits to some extent with the metal, thus interfering with the regular crystal growth of the metal. Such continuous interference results in a smaller grain size, and hence a smoother deposit.³

Water is used in the greatest quantities compared to any other chemical in the plating shop. The purity required depends on the nature of the process being used. Air in large amounts, carbonates and metals, especially iron, in water used by the electroplater can result in unsatisfactory plating. If available water is unsuitable because of impurities, it must be processed to remove them. Activated charcoal, strong bases dialysis and chelating agents are often used to prepare water for preparation of plating baths. In addition, filters are used to remove solids from baths in use.⁴

POWER SOURCES

Direct current for small scale plating operations which require less than five amperes is usually supplied by batteries. Intermediate plating operations from five to one thousand amps usually use rectifiers. Selenium, germanium and silicon today

FOOTNOTES

1 "Electrometallurgy," Encyclopaedia Britannica, 1962, VIII, 303.

2 Ibid., p. 303.

3 "Electroplating," Encyclopaedia Britannica, 1962, VIII, 341.

4 Marjorie A. Brimi and James R. Luck, Electrofinishing (New York: American Elsevier Pub. Co., 1965), pp. 4-5.

5 "Electroplating," VIII, 340.

6 "Electrometallurgy," VIII, 303.

7 J. K. Dennis and T. E. Such, Nickel and Chromium Plating (New York: Halstead Press, 1972), pp. 289-290.

8 Brimi and Luck, p. 49.

9 Ibid., p. 50.

10 Ibid., p. 12.

11 Ibid., p. 30.

12 Ibid., p. 32.

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